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Technical Report 822

The Effect of Target Background and Aspect Angle on Performance of Stinger Teams in the Realistic Air Defense Engagement System (RADES)

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United States Army Research Institute
for the Behavioral and Social Sciences

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Science Applications International Corporation

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The Realistic Air Defense Engagement System (RADES) is a validated Forward Area Air Defense (FAAD) engagement simulation that has been used to test and train FAAD troops. Engagement performance data are collected from troops and weapons while they engage sub-scale jet and helicopter aircraft in a desert environment. The experiment measured the performance of 12 Stinger teams under conditions that varied the visual information available. Jet aircraft were flown in two different attack maneuvers (pop-up or lay-down) against two types of background (terrain or sky). Helicopters popped up from defilade in two different aspects (0 degrees or 90 degrees) against either a sky or terrain background. Aircraft were either friendly (U.S.) or hostile (Soviet Bloc) scale models. Performance varied with conditions, being better in conditions of pop-up maneuver, sky background, and 90-degree aspect. The greater the visual contrast between target and background and the greater the visual size of the target, the better was the engagement
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performance. Detection performance was also better when the search sector was effectively reduced by the presentation of multiple targets. RADES results were compared with results from other published field experiments, where appropriate, and demonstrated consistency with those results.

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FOREWORD

The Crew Weapons Performance Team of the Fort Bliss Field Unit of the Army Research Institute for the Behavioral and Social Sciences (ARI) performs research and development in air defense soldier-system performance integration. In the past, Forward Area Air Defense (FAAD) research has been limited by lack of a dedicated testing facility. In response to this need, the Fort Bliss Field Unit has designed, developed, and validated such a facility. This Realistic Air Defense Engagement System (RADES) uses actual FAAD weapon systems and crews to engage subscale hostile and friendly aircraft in a desert environment. This report describes the performance in RADES by Stinger teams tested under tactical and doctrinal conditions likely to occur in the air defense battle. This research was designed to provide a baseline level of performance against which data from later mission-driven experiments could be compared.

The research discussed responds to the Fort Bliss Field Unit's mission to fabricate and test a simulation facility for the evaluation of SHORAD/MANPAD air defense weapon system personnel (DD 1498 #DA300370). This research was authorized by a joint study concept memorandum between ARI and the U.S. Army Air Defense Artillery School (USAADASCH) entitled "Portable SHORAD/MANPAD Facility for Simulation, Training, and Evaluation" dated 9 November 1981. These results were first presented at the 26th Quadripartite Working Group, Army Operations Research Symposium in August 1986. Human performance data from this research have been used by the Directorate of Training and Doctrine at USAADASCH to validate engagement standards (SHORAD Weapons System Program Review, October 1988).

EDGAR M. JOHNSON
Technical Director

THE EFFECT OF TARGET BACKGROUND AND ASPECT ANGLE ON PERFORMANCE OF STINGER TEAMS IN THE REALISTIC AIR DEFENSE ENGAGEMENT SYSTEM (RADES)

EXECUTIVE SUMMARY

Requirement:

To determine a baseline level of performance for Stinger teams engaging aircraft under realistic tactical and doctrinal conditions. To assess the impact of target viewing characteristics on the engagement performance of Stinger teams.

Procedure:

The Realistic Air Defense Engagement System (RADES) is an air defense simulator consisting of subscale aircraft, an aircraft location system, actual air defense weapon systems, and electronic interfaces that connect the weapon and operators to a sophisticated data collection and communication system. When using the simulator, Forward Area Air Defense (FAAD) crews are taken to the RADES mini-range, the weapon is connected to the interface, the crew is given an operations order and alerted, and data are automatically collected from the weapon and crew as they respond to the RADES aircraft.

In this experiment, data were collected from 12 Stinger teams engaging both fixed-wing (FW) and rotary-wing (RW) aircraft. FW aircraft were presented flying one of two attack maneuvers (pop-up or lay-down) against one of two background conditions (terrain or sky). RW aircraft popped up from defilade in one of two aspect angles (0 degrees or 90 degrees) against one of two backgrounds (terrain or sky). Teams were placed in Weapons Control Status Tight, requiring them to use visual criteria for tactical identification of aircraft. Data included times and ranges for critical engagement events, aircraft identification accuracies, and kill or miss determinations.

Findings:

Currently, Stinger teams are required to detect, identify, track, and range aircraft visually. This research showed that battlefield conditions that affect human visual perception have a substantial effect on performance of the Stinger fire unit. For example, substantial negative effects upon detection, identification, and fire were produced by reducing the visual contrast between aircraft and background. Further, larger aircraft were

detected, interrogated, and identified earlier than smaller ones. Also, helicopters, when presented hovering in quartering aspect (90 degrees to observer), were detected and identified earlier than when the same helicopters were presented in frontal aspect (0 degrees). Finally, the case was made that doctrinal requirements to use human vision for tactical identification (as in Weapons Control Status Tight) impose significant limitations on the capabilities of Stinger teams to engage hostile aircraft at maximum effective range.

Utilization of Findings:

To date, RADES has provided the air defense community with (1) low-cost, accurate analyses of air defense performance and the effectiveness of potential system modifications; (2) realistic air defense training; and (3) manpower, personnel, and training data to ensure that future air defense systems effectively employ human operators and crews. The data produced by the current research have been used for the latter purpose. The results of this Baseline Stinger Experiment have been briefed to and provided to the proponent (Major General Infante, Commanding General of Fort Bliss), MANPRINT analysts, and soldier-system modelers (Line-of-Sight Forward Operator Engagement Model).

Further development and use of this testbed will lead to recommendations for air defense systems hardware, procedural modifications, and a realistic, collective, fire-unit trainer and evaluator.

THE EFFECT OF TARGET BACKGROUND AND ASPECT ANGLE ON PERFORMANCE OF STINGER TEAMS IN THE REALISTIC AIR DEFENSE ENGAGEMENT SYSTEM (RADES)

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THE EFFECT OF TARGET BACKGROUND AND ASPECT ANGLE ON PERFORMANCE OF STINGER TEAMS IN THE REALISTIC AIR DEFENSE ENGAGEMENT SYSTEM (RADES)

INTRODUCTION

An air defender's task is to destroy hostile aircraft, or disrupt their mission, while refraining from engaging friendly aircraft. Experience has shown this to be no easy task. Aircraft are difficult to hit. In World War II the Germans required 12,000 antiaircraft shells for each Allied aircraft destroyed (Dunnigan, 1983, p. 121). Thirty years later the ratio had not improved much. During the Vietnam and the Arab-Israeli wars over 10,000 shells were required for each aircraft downed (Dunnigan, 1983, pps. 121, 122).

Further, aircraft are overbuilt, with many redundant systems. Even when hit by air defense munitions, destruction is not assured. For example, half the Israeli A-4 jets hit with portable air defense missiles in the 1973 war were able to return to base (Dunnigan, 1983, p. 124).

Finally, while it is difficult enough to shoot down aircraft, the problem is exacerbated by the requirement to identify and shoot enemies, not friends. During the 1973 Arab-Israeli War, the Arabs launched 2100 surface-to-air missiles. For this expenditure they downed 85 aircraft, 45 of which were their own (Dunnigan, 1983, p. 123). The destruction of friendly aircraft (called "fratricide") would be a particularly serious problem in any future US/Soviet Bloc confrontation. Not only are military aircraft expensive, costing many millions of dollars each, but the Soviet Union continues to enjoy a numerical advantage in such aircraft (Soviet Military Power 1984, pps. 28, 74, 75, & 98; Soviet Military Power 1987, pps. 92, 93, 121, & 122).

The Army is committed to protecting itself from hostile aircraft. But aircraft are difficult to hit and kill. Further, misidentifications which lead to fratricide would make any tactical situation worse. Hence, the Army needs weapons, doctrine, tactics, and training which will maximize attrition while minimizing fratricide.

Army Air Defense systems are usually categorized as either High-to-Medium Altitude Air Defense (HIMAD) or Forward Area Air Defense (FAAD). The HIMAD systems--such as Patriot and Hawk--are all missile systems positioned in the division and corps rear areas. The defining characteristics of such systems are that they have an effective altitude greater than 5 kilometers (km) and an effective range greater than 10 kilometers. These systems employ computer-controlled radar to automatically detect, track, and identify targets. HIMAD operators fight the air war from a position at a console, staring at a display screen, while inside a mobile van. The HIMAD systems are responsible for defense against all but low altitude aircraft.

The FAAD systems employ guns or missiles against relatively low-flying aircraft in the forward battle area. These systems are designed to protect maneuver units from ground-attack jets and helicopters. The FAAD systems have

an effective altitude lower than 5 kilometers and an effective range less than 10 kilometers. These systems require the air defender to detect, track, and identify targets visually. The FAAD troops fight their air war manually--either from the ground or from the turret of a tracked vehicle. This report is concerned only with Forward Area Air Defense.

BACKGROUND

The projected FAAD battlefield will include multiple, hostile and friendly, jets and helicopters. Some of these aircraft will be attacking local targets, while others will be transiting to attack targets in the rear (cf., Little & Vane, 1986). Some aircraft will be attacking the air defense positions themselves, since this is standard operating procedure among military pilots. Meanwhile, air defenders will be expected to do their job amidst smoke, noise, ground-fire, and the other accompaniments of modern warfare.

Current FAAD weapons (in 1987) include the man-portable Redeye and Stinger infrared radiation (IR)-seeking missile systems, the vehicle-mounted Chaparral IR-seeking missile system, and the towed or vehicle-mounted Vulcan gun system.

The FAAD branch of Army Air Defense has recently been undergoing a renaissance. Current plans call for new FAAD weapons linked by a new command, control, and intelligence (C2I) network. This new system is called FAADS (Forward Area Air Defense System). The FAADS will likely include a Pedestal-Mounted Stinger weapon system (also called Line-of-Sight Rear), a Line-of-Sight Forward weapon system, a Non-Line-of-Sight Rear weapon system, the new C2I network, and a combined arms capability (cf., Little & Vane, 1986). These systems are still undergoing development and testing. It is certain, however, that the current FAAD systems (such as Stinger) will remain in the inventory of the Regular Army at least through FY96 (Greenway, 1987). These same systems will remain with the Reserve Component well beyond this date (Greenway, 1987). Hence, performance assessments of current FAAD units using current FAAD weapons (such as is reported in this document) remain a valuable source of data for combat developments and battlefield modeling.

Stinger is a shoulder-fired, IR (heat-seeking) guided missile system. The missile requires no control from the gunner after being fired. Stinger has an identification friend or foe (IFF) subsystem to aid the team in aircraft identification. The IFF subsystem returns one of three tonal patterns depending upon whether the reply to interrogation is classified as "true friend" (mode 4), "possible friend" (mode 3), or "unknown." Operations by a Stinger team at night or in bad weather are restricted by the inability to see and identify the target. The Stinger weapon system consists of four basic items: weapon round, IFF subsystem, shipping and storage containers, and transport harness. The Stinger weapon round is made up of a missile round (consisting of a Stinger missile within a launch tube) mated to a separate gripstock. A battery/coolant unit (BCU) is inserted into the weapon round to provide prelaunch power to the system. All three items--missile round, separable gripstock with IFF antenna, and BCU--are necesary to have an operational weapon. The weapon is 60 inches long, and, with BCU inserted,

weighs 34.7 pounds. For IFF capability, an IFF interrogator is connected by cable from the gunner's cartridge belt to the weapon. A Stinger team is issued 4 weapon rounds plus 2 replacement missile rounds (FM 44-18-1, 1984).

Stinger replaces the Redeye weapon system. It gives the following advantages over Redeye: increased missile velocity permitting engagement of high speed targets, increased capability to engage directly incoming targets, increased capability against IR countermeasures, means for identification of friendly aircraft (IFF), and increased range. Stinger is meant to provide short-range air defense for maneuver and combat support units. It is designed to counter both ground-attack jet aircraft as well as helicopter, observation, and transport aircraft.

A Stinger team (Military Occupational Specialty: 16S) consists of a team chief, who is usually an E4/E5, and a gunner, who is usually an E2/E3. The chief is responsible for receiving alerts, identifying the target, and ordering the gunner to fire (the "engagement command"). The gunner is responsible for interrogating the target with IFF, activating the weapon, tracking, acquiring, and ranging the target, and, on order, firing the weapon. When faced with multiple targets, both team members are permitted to engage aircraft with two Stinger systems.

Both team members are expected to search for targets. Actions taken upon detection of an aircraft will vary depending upon many factors, including: the hostile or friendly intent of the aircraft, and the Weapons Control Status. The intent of an aircraft is determined by a combination of factors, including: its response to IFF interrogation, its specific identity (e.g., F-16, MiG-27), and its actions. There are three Weapons Control Statuses: Weapons Hold, Weapons Tight, and Weapons Free. In Weapons Hold Status the team does not interrogate the target and fires only in self-defense. In Weapons Tight Status, the team does interrogate the target but fires only when the target is positively identified as hostile. In Weapons Free Status, the team interrogates the target and fires if the target is not positively identified as friendly. Thus, unknown targets are engageable in Weapons Free Status. The right to fire in defense of themselves or their defended asset is never denied, regardless of Weapons Control Status.

Sometimes the team will receive early warning of the approach of aircraft into their area of operations. This warning can occur over voice radio or the Target Alert Data Display Set (TADDS). The TADDS receives information about target location and possible identification from the Forward Area Alerting Radar (FM 44-18-1, 1984).

Once alerted, the Stinger team searches visually for aircraft. Aircraft may be detected by either team member, and then communicated to the other ("contact, twelve o'clock") using their assigned primary target line (PTL) as reference for twelve o'clock. Once a target is detected, the gunner will begin to track the target and interrogate it with the IFF subsystem. Meanwhile, the team chief will be attempting to identify the target visually, often with binoculars. If the target is identified as hostile the team chief will issue an engagement command. The gunner will then engage the aircraft, assuming he has acquired it with the weapon and it is within range. Distinctive tones emitted by the Stinger tell the gunner when he has acquired and locked-onto the target.

Clearly, the soldier is very much "in the loop" during a Stinger engagement sequence. The soldier's visual system is used for search, detection, identification, tracking, ranging, and for assessment of effects. Hand-eye coordination is required for tracking. The soldier's auditory system is used for identifying the tones associated with IFF interrogation as well as IR acquisition and IR lock-on. Because Stinger is so heavily dependent upon the soldier's perceptual and motor capabilities it becomes a critical research issue to determine the soldier's effect on overall system performance.

APPROACH

The RADES testbed was developed to provide a cost-effective means of performing controlled research on issues affecting FAAD system performance. In the past RADES has been used to test new weapon system concepts (e.g., Tripod Mounted Stinger; Lockhart & Johnson, 1985) and new techniques of collective training (e.g., Pedestal Mounted Stinger crewmembers; Barber, Drewfs, & Lockhart, 1987). The current report describes research performed to examine specific doctrinal and tactical conditions likely to occur on the battlefield. The approach taken by our team has been to examine those soldier performance issues likely to have a substantial effect upon the overall performance envelope of the FAAD fire unit. Since so many of the current FAAD engagement tasks require the human visual system, factors which affect the visual system would be expected to affect FAAD performance.

The purpose of this Stinger Baseline Experiment was to investigate the performance of Stinger teams as they engaged fixed-wing (FW) and rotary-wing (RW) aircraft under conditions chosen to vary the visual information available. The independent variables manipulated in this Experiment were FW aircraft maneuver, RW aircraft aspect, aircraft background (for both FW and RW), and aircraft intent (for both FW and RW). Previous research suggests that these independent variables produce a range in air-defense-relevant performance (i.e., Wokoun, 1960; Kirkland, 1972; Baldwin, 1973; CDEC, 1978; CDEC, 1980). Since this was designed to be a "Baseline Experiment," it was hoped that the data produced would be used for comparisons against later, mission-driven, experiments in RADES.

Specifically, hostile and friendly FW aircraft (i.e., jets) were presented singly flying either a pop-up or a lay-down attack maneuver against either a terrain or a sky background. Hostile and friendly RW aircraft (i.e., helicopters) were presented singly in either a frontal aspect (face-view, 0 degrees) or a quartering aspect (side-view, 90 degrees) against either a terrain or a sky background. Finally, two hostile RW aircraft were presented simultaneously with both in either a frontal or a quartering aspect against either a terrain or a sky background. Interestingly, these same variables were independently ranked as being among the most important information items by a sample of 90 FAAD crewmembers surveyed by Fallesen (1985).

All aircraft in RADES were painted desert camouflage colors. It was hypothesized that presenting such aircraft against a desert terrain background would harm detection and identification performance. After all, to lower detection and identification performance is the reason military equipment is camouflaged.

The FW aircraft were presented performing two different low-level attack maneuvers (FM 44-3, 1984, pps. 2-15, 2-16). During a lay-down maneuver, the remote pilot flew the model jet at a low altitude to within approximately 1.5 (fullscale) kilometers of the Stinger team, turned, and then returned to base. During a pop-up maneuver, the remote pilot flew the aircraft at a low altitude to within approximately 2.8 (fullscale) kilometers of the team, popped-up, rolled, dived, turned, and then returned to base. Both maneuvers brought the airplane to within approximately 1.5 (fullscale) kilometers of the Stinger team. The pop-up maneuver, however, exposed more of the aircraft to the team both during the pop-up and the roll. Thus, it was hypothesized that identification performance would be better for the pop-up conditions, relative to the lay-down conditions.

Helicopters presented in quartering aspect provide a larger visual stimulus than they do when presented frontally. Thus, it was hypothesized that air defenders would detect and identify the RW targets earlier and with greater accuracy when they were presented in 90 degree aspect than when they were presented in 0 degree aspect.

These aircraft were presented to Stinger teams who were operating in Weapons Control Status Tight. Tight was chosen because it is a doctrinal constraint on engagement which will likely be employed in war to reduce fratricide. Since troops in Weapons Tight must use visual criteria to determine hostile or friendly intent, variations in the target viewing conditions were expected to show large effects upon performance under this doctrinal restriction.

Data were collected on the following Stinger team engagement actions: detection, IFF interrogation, visual identification, IR lock-on, and fire. These actions are presented in terms of range of the aircraft at engagement event in kilometers and time of event in seconds. Since RADES aircraft are subscale, all ranges are presented in terms of fullscale range equivalents by multiplying the measured range by the scaling factor.

In addition to these task performance measures, summary performance measures were also computed. These included proportion correct identifications, proportion engaged, proportion fratricide, proportion attrition, and proportion of hostile aircraft releasing ordnance.

METHOD

Participants

Twelve Stinger teams from the Stinger Platoon, Headquarters and Headquarters Troop, Third Armored Cavalry Regiment, Fort Bliss, Texas participated. Each team consisted of two soldiers, an E4/E5 team chief and an E1/E2 gunner. MOS for all soldiers was 16S. Team chiefs had a mean age of 24.3 years, a mean time in service of 74.1 months, and a mean time in MOS of 43.0 months. The median rank for team chiefs was E5. Gunners had a mean age of 19.4 years, a mean time in service of 7.3 months, and a mean time in MOS of 5.7 months. The median rank for gunners was E2.

The RADES Simulation

RADES is located at Condron Field, White Sands Missile Range, New Mexico. This desert area contains mountains 10 km to the west. Visibility is usually in excess of 60 km. Skies are usually clear.

A detailed description of the RADES simulation can be found in the RADES Validation Report (Drewfs, Barber, Johnson, & Frederickson, 1988). RADES employs FAAD crews and teams, manning instrumented FAAD weapon systems, for simulated engagement of subscale aircraft. RADES aircraft are of two types—flying 1:7 scale "jets" and nonflying 1:5 scale "helicopters". The jets represent friendly (USA) and hostile (Soviet Bloc) attack aircraft. The helicopters, which pop-up from hidden positions and hover, represent friendly (USA) and hostile (Soviet Bloc) attack/utility aircraft. The friendly aircraft presented in the current experiment were the F-16 Fighting Falcon (FW) and the AH-1 Cobra (RW). The hostile aircraft presented were the MiG-27 Flogger (FW), the Mi-8 Hip (RW), and the Mi-24 Hind (RW).

FW aircraft were presented singly, flying either pop-up or lay-down maneuvers, incoming from an azimuth which either had a terrain or a sky background. Approximately half of the 90-degree search sector provided mountainous terrain as a background, while the other half had an unobstructed sky background. FW aircraft flew at a (fullscale) velocity of approximately 600 knots. FW flight path offset was approximately 1.5 km from the Stinger team. An automatic position/location system determined the location and range of the FW aircraft during trials. [This system is described in Drewfs, Barber, Johnson, and Frederickson (1988).] RW aircraft popped-up, under computer control, for durations of 40 seconds. RW aircraft were presented either singly or doubly, in either face-view or side-view orientations, against either a terrain or a sky background. RW targets were positioned behind sand dunes, when lowered, at a fullscale distance of approximately 3 km from the Stinger team. On trials when two RW aircraft were presented simultaneously, they were separated by approximately 30 degrees. All aircraft were equipped with an IR source to which the Stinger weapon could acquire and lock-on. All targets were painted in "sand and spinach" desert camouflage colors.

All teams engaged targets with the same Stinger Tracking Head Trainer (Training Set, Guided Missile, M134). The IFF Simulator was modified to produce an "unknown" return upon interrogation. Interface electronics automatically recorded critical Stinger engagement events (e.g., IFF interrogation, IR lock-on, fire). Verbal engagement events (e.g., detection, tactical identification) were keyed-in during trials by a data collector who monitored the team's communication net. A "tactical identification" requires the team leader to determine whether the aircraft is "friendly" or "hostile". That is, RADES did not require team leaders to state aircraft model number (e.g., MiG-27) or NATO designation (e.g., Flogger). All weapon and verbal engagement events were automatically tagged as to time and range of aircraft at occurrence. In addition, sensors attached to the Stinger automatically kept track of where the weapon was pointing in azimuth and elevation.

Procedure

One team was brought to the RADES site per day. During the hour-long trip out to site, teams were briefed about RADES and questions were answered, when applicable. Stinger field manuals were provided for review of key engagement actions, command and control, etc. Once at RADES, a team was given an Operations Order stating mission, enemy, sector of responsibility, sector boundaries, and primary target line. Left and right sector boundaries and PTL were marked with stakes. Each team received one RW practice trial before the test began. A test trial began with an Air Defense Alert Condition Red. During a trial the team was instructed to engage targets "as if it was the real thing". Each trial lasted from one to three minutes. A trial ended with an Air Defense Alert Condition White. Between trials, the Stinger was placed on a platform and the team sat in a bunker with their backs to the RADES range.

The Weapons Control Status for all trials was Tight (i.e., positive, visual identification of hostile intent required before fire). The IFF return was always "unknown". An early warning of approximately 30 seconds was provided on every trial. Teams were not cued as to aircraft type, identification, or incoming azimuth. All teams used 7 x 50 binoculars for identification but not for detection.

For clarity of exposition this Experiment will be reported in three sub-sections. The Fixed-Wing Sub-Experiment contained 8 engagement trials per team [intent (hostile or friendly) x maneuver (pop-up or lay-down) x background (terrain or sky) = 8]. The Single Rotary-Wing Sub-Experiment also contained 8 trials per team [intent (hostile or friendly) x aspect (front or side) x background (terrain or sky) = 8]. The Double Rotary-Wing Sub-Experiment contained 4 trials per team [aspect (front or side) x background (terrain or sky) = 4]. All 12 teams received a different, counterbalanced, presentation order of these same 20 engagement trials in this repeated-measures design.

RESULTS

General

In this Stinger Baseline Experiment, variables were manipulated systematically in an effort to determine a range of performance levels. The data will be used for comparisons against later, mission-driven, experiments in RADES. In addition, these data should prove useful to air defense modelers. For these reasons, the data from this Experiment are presented in a detailed, cell-by-cell fashion. The reader who does not need to examine these details is invited to skip to the sub-section entitled "Summary Engagement Times for Hostile Fixed-Wing and Hostile Rotary-Wing Aircraft".

Data were analyzed separately for the three Sub-Experiments (FW, RW-Single, RW-Double). For the FW Sub-Experiment the data of interest were fullscale engagement ranges, engagement times, and proportion correct actions. For the Single and Double RW Sub-Experiments the data of interest were

engagement times and proportion correct actions. (Engagement ranges are irrelevant for the RW Sub-Experiments because the stand-mounted helicopters do not change position within an experiment.) Longer incoming engagement ranges for FW aircraft generally indicate better performance. Also, shorter engagement times generally indicate better performance.

Data presented in tables are the arithmetic mean (Mean), the standard deviation (SD), and the number (N) of data points upon which these statistics are based. It will be noted throughout this Results section that the number of data points is not constant for each engagement event. This is as it should be. RADES does not record an engagement event when the Stinger team does not perform that action. In the "heat of battle" teams sometimes omit one or more engagement actions. For inferential statistical analysis, when data points were missing cell means were used as replacement values.

Fixed-Wing Sub-Experiment: Engagement Event Ranges

Engagement event ranges for conditions of the FW Sub-Experiment are presented in Tables 1 through 5, by dependent variable type. Ranges for the detection announcement (Table 1), the IFF-button push (Table 2), and the identification (ID) announcement (Table 3) are presented for both hostile and friendly aircraft. Ranges for IR lock-on (Table 4) and fire-trigger pull (Table 5) are presented only for hostile aircraft.

Table 1
Detection Range in Kilometers for Fixed-Wing Sub-Experiment

Friendly Aircraft: F-16

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	3.6	3.8	8.1	8.0
SD	1.4	1.7	2.4	2.3
N	12	12	12	12

Hostile Aircraft: MiG-27

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	3.3	3.2	7.6	8.5
SD	1.4	1.2	1.6	1.6
N	12	12	12	12

Table 2
IFF Range in Kilometers for Fixed-Wing Sub-Experiment

Friendly Aircraft: F-16

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	3.0	3.2	7.8	5.0
SD	1.3	1.6	2.1	2.9
N	10	9	7	9

Hostile Aircraft: MiG-27

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	3.3	2.6	6.2	7.3
SD	1.8	0.8	2.5	1.8
N	12	10	10	10

Table 3
Identification Range in Kilometers for Fixed-Wing Sub-Experiment

Friendly Aircraft: F-16

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	2.5	2.1	3.5	2.6
SD	0.9	0.8	1.8	0.9
N	12	12	12	12

Hostile Aircraft: MiG-27

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	2.3	2.4	3.9	3.6
SD	0.5	1.0	1.7	2.1
N	12	12	12	12

Table 4
Lock-On Range in Kilometers for Fixed-Wing Sub-Experiment

Hostile Aircraft: MiG-27

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Incoming*				
Mean	1.8	2.1	4.0	3.9
SD	0.5	0.7	1.6	2.0
N	3	2	7	5
Outgoing*				
Mean	2.7	2.3	3.8	2.4
SD	0.7	0.7	1.0	1.1
N	7	7	3	5

* Aircraft presented against the sky background were more likely to be locked-onto while they were still incoming (12/20 = 0.60), while aircraft presented against the terrain background were more likely to be locked-onto after they had passed the turn point and were outgoing (14/19 = 0.74). Incoming ranges and outgoing ranges cannot be combined meaningfully. Hence, the presentation of the descriptive statistics in this fashion. Unless otherwise noted, ranges presented throughout this report can be assumed to be incoming.

Table 5
Fire Range in Kilometers for Fixed-Wing Sub-Experiment

Hostile Aircraft: MiG-27

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Incoming*				
Mean	1.9	2.2	3.0	3.3
SD	0.1	0.1	1.3	1.6
N	3	2	6	5
Outgoing*				
Mean	3.6	3.4	4.4	3.1
SD	0.7	0.6	0.7	1.1
N	8	7	4	6

* Aircraft presented against the sky background were more likely to be fired upon while they were still incoming (11/21 = 0.52), while aircraft presented against the terrain background were more likely to be fired upon after they had passed the turn point and were outgoing (15/20 = 0.75). Incoming ranges and outgoing ranges cannot be combined meaningfully. Hence, the presentation of the descriptive statistics in this fashion. Unless otherwise noted, ranges presented throughout this report can be assumed to be incoming.

All of the FW aircraft presented were detected (96/96 = 1.00). Detection ranges were analyzed by a three-factor, repeated-measures Analysis of Variance (intent x maneuver x background; Keppel, 1973). There was a significant main effect of target background upon detection range ($F = 135.35$, $df = 1/11$, $p < .001$). The same aircraft when presented against a sky background were detected at a greater mean range (8.1 km) than when they were presented against a terrain background (3.5 km). All other main effects and interactions were not statistically significant.

Eighty percent of the FW aircraft presented were interrogated by electronic IFF (77/96 = 0.80). IFF ranges were analyzed by a three-factor, repeated-measures Analysis of Variance (intent x maneuver x background). There was a significant main effect of target background upon IFF performance ($F = 89.08$, $df = 1/11$, $p < .001$). The same aircraft when presented against a sky background were interrogated at a greater mean range (6.6 km) than when they were presented against a terrain background (3.0 km). The three-way interaction (intent by maneuver by background) was significant ($F = 13.28$, $df = 1/11$, $p < .01$). This interaction shows that the background effect (sky range > terrain range) for the F-16 was greatest during the pop-up maneuver,

whereas the background effect for the MiG-27 was greatest during the lay-down maneuver. All other main effects and interactions were not statistically significant.

All of the FW aircraft presented were identified (96/96 = 1.00). Identification ranges were also analyzed using a three-factor, repeated-measures ANOVA. There was a significant main effect of target background upon identification performance ($F = 8.06$, $df = 1/11$, $p < .025$). Again, the same aircraft when presented against a sky background were identified at a greater mean range (3.4 km) than when they were presented against a terrain background (2.3 km). No other main effects or interactions were significant.

Eighty-one percent of the hostile FW aircraft presented were locked-onto by the Stinger teams (39/48 = 0.81). Aircraft presented against the sky background were more likely to be locked-onto when incoming (12 of 20) than when outgoing (8 of 20). The mean incoming range for IR lock-on for sky background was 4.0 km. Aircraft presented against the terrain background were more likely to be locked-onto after crossover when they were outgoing (14 of 19) than when incoming (5 of 19). The mean outgoing range for IR lock-on for terrain background was 2.5 km. As stated above, crossover was at 1.5 km offset from the Stinger position. This effect of background upon lock-on performance, the difference between 4.0 km incoming and 2.5 km outgoing, was substantial.

Eighty-five percent of the hostile FW aircraft presented were fired upon by the Stinger teams (41/48 = 0.85). Aircraft presented against the sky background were slightly more likely to be fired upon when incoming (11 of 21) than when outgoing (10 of 21). The mean incoming range for fire for sky background was 3.1 km. Aircraft presented against the terrain background were more likely to be fired upon after crossover when they were outgoing (15 of 20) than when incoming (5 of 20). The mean outgoing range for fire for terrain background was 3.5 km. This effect of background upon fire performance, the difference between 3.1 km incoming and 3.5 km outgoing, was substantial.

Fixed-Wing Sub-Experiment: Engagement Event Times

Engagement event times for conditions of the FW Sub-Experiment are presented in Tables 6 through 10, by dependent variable type. Times for the detection announcement are presented in Table 6. The trial clock was started when a FW aircraft passed the 10 km point at the beginning of each run. Thus, the times presented in Table 6 represent the time, in seconds, from "target availability" at 10 km until the detection announcement was made.

Table 6
Detection Time in Seconds for Fixed-Wing Sub-Experiment*

Friendly Aircraft: F-16

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	27.3	26.7	8.8	9.2
SD	5.3	6.9	9.3	9.3
N	12	12	12	12

Hostile Aircraft: MiG-27

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	28.6	29.4	13.1	8.0
SD	5.4	5.4	7.4	6.2
N	12	12	12	12

* Time from target availability (at 10 km point) until detection announcement.

Times from the detection announcement until IFF-button push, identification announcement, IR lock-on, and fire-trigger pull are presented in Tables 7, 8, 9, and 10, respectively. Thus, the times presented in Tables 7 through 10 reflect the time in seconds from the detection event until the engagement event of interest. This method of calculating engagement times prevents differences in the time of detection from biasing the interpretation of all subsequent event times. As before, times for detection, IFF, and ID are presented for both friendly and hostile FW aircraft. Times for lock-on and fire are only presented for trials employing hostile FW aircraft.

Table 7
IFF Time in Seconds for Fixed-Wing Sub-Experiment*

Friendly Aircraft: F-16

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	3.2	0.9	7.0	8.6
SD	3.7	2.3	6.6	8.3
N	10	9	7	9

Hostile Aircraft: MiG-27

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	0.2	2.2	6.2	4.5
SD	4.6	4.9	5.9	3.9
N	12	10	10	10

* Time from detection announcement until IFF-button push.

Table 8
Identification Time in Seconds for Fixed-Wing Sub-Experiment*

Friendly Aircraft: F-16

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	12.7	11.1	18.0	25.9
SD	5.6	5.9	9.1	10.5
N	12	12	12	12

Hostile Aircraft: MiG-27

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	9.1	9.9	19.7	22.7
SD	3.5	7.0	11.5	11.6
N	12	12	12	12

* Time from detection announcement until ID announcement.

Table 9
Lock-On Time in Seconds for Fixed-Wing Sub-Experiment*

Hostile Aircraft: MiG-27

Statistic	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Mean	11.8	9.9	19.8	22.7
SD	4.5	4.6	11.2	8.8
N	10	9	10	10

* Time from detection announcement until IR lock-on.

Table 10
Fire Time in Seconds for Fixed-Wing Sub-Experiment*

	Hostile Aircraft: MiG-27			
	Terrain Background		Sky Background	
Statistic	Pop-Up	Lay-Down	Pop-Up	Lay-Down
Mean	15.3	14.2	25.7	27.0
SD	4.2	4.8	9.8	8.8
N	11	9	10	11

* Time from detection announcement until fire-trigger pull.

Table 11 presents the times from the ID announcement until fire, for conditions with hostile aircraft. The inclusion of this table allows the reader to compare three critical event times: target availability to detect (Table 6), detect to ID (Table 8), and ID to fire (Table 11).

Table 11
ID-to-Fire Time in Seconds for Fixed-Wing Sub-Experiment*

	Hostile Aircraft: MiG-27			
	Terrain Background		Sky Background	
Statistic	Pop-Up	Lay-Down	Pop-Up	Lay-Down
Mean	6.1	5.4	9.1	6.0
SD	3.5	3.7	7.0	3.6
N	11	9	10	11

* Time from ID announcement until fire-trigger pull.

Detection times (target available to detect announcement) were analyzed with a three-factor, repeated-measures Analysis of Variance (intent x maneuver x background). There was a significant main effect of target background upon detection time ($F = 171.98$, $df = 1/11$, $p < .001$). Aircraft when presented against a sky background were detected much earlier (mean = 9.8 sec.) than when they were presented against a terrain background (mean = 28.0 sec.). No other main effects or interactions were statistically significant.

IFF times (detect to IFF) were also analyzed with a three-factor, repeated-measures ANOVA. There was a significant effect of target background upon IFF time ($F = 7.23$, $df = 1/11$, $p < .05$). Targets presented against a

terrain background were interrogated sooner after detection (mean = 1.6 sec.) than were those presented against a sky background (mean = 6.6 sec.). No other main effects or interactions were significant.

Identification times (detect to ID) were analyzed by a three-factor, repeated-measures ANOVA. Once again, there was a significant main effect of background upon performance ($F = 25.60$, $df = 1/11$, $p < .01$). Targets presented against a terrain background were identified sooner after detection (mean = 10.7 sec.) than were those presented against a sky background (mean = 21.6 sec.). There was also an effect of aircraft maneuver upon ID ($F = 7.17$, $df = 1/11$, $p < .05$). Aircraft when flying the pop-up attack maneuver were identified earlier (mean = 14.9 sec.) than when they were flying the lay-down attack maneuver (mean = 17.4 sec.). Finally, there was a significant background-by-maneuver interaction ($F = 7.83$, $df = 1/11$, $p < .05$). This interaction represents the fact that the effect of maneuver (pop-up time < lay-down time) occurred only when aircraft were presented against a sky background (see Table 8). No other main effects or interactions were statistically significant.

Lock-on times (detect to lock-on) for hostile aircraft were analyzed by a two-factor, repeated-measures ANOVA (background x maneuver). Again, there was a significant effect of background ($F = 24.03$, $df = 1/11$, $p < .001$). Aircraft presented against a terrain background were locked-onto considerably earlier (mean = 10.9 sec.) than were those presented against a sky background (mean = 21.3 sec.). No other main effect or interaction was statistically significant.

Fire times (detect to fire) for hostile aircraft were analyzed with a two-factor, repeated-measures ANOVA. There was a significant main effect of background on time to fire ($F = 26.34$, $df = 1/11$, $p < .001$). Targets presented against a terrain background were fired on in less time (mean = 14.8 sec.) than were those presented against a sky background (mean = 26.4 sec.). Neither the main effect of maneuver nor the background-by-maneuver interaction was statistically significant.

Times from the detection announcement until IFF, ID, lock-on, and fire (respectively) were shorter for terrain background than for sky background. This effect of background upon engagement time is discussed in detail later in this report (cf., Tables 30, 32, and Discussion section).

ID-to-fire times for hostile targets were analyzed using a two-factor, repeated-measures ANOVA. There were no statistically significant effects of either maneuver, or background, or the interaction of the two. The mean overall time from ID to fire was 6.7 seconds.

Fixed-Wing Sub-Experiment: Proportion Correct Identifications

Participants in RADES are required to make a tactical identification (either "friendly" or "hostile"). Therefore, for either friendly aircraft or hostile aircraft, participants would be expected to make correct identifications by chance alone 50 percent of the time. In fact, the overall proportion correct (PC) identification rate for the friendly (F-16) model was

0.40. This did not differ significantly from chance ($\underline{Z} = -0.69$, $\underline{N} = 12$, $\underline{p} > .10$; Bruning & Kintz, 1968, p. 197). We have since procured a different, and more realistic, F-16 model. For the present, no further identification data from this low-fidelity model will be reported.

The overall proportion correct identification rate for the hostile (MiG-27) model was 0.87. This level of performance was significantly better than chance ($\underline{Z} = 2.60$, $\underline{N} = 12$, $\underline{p} < .01$). The correct hostile ID rate for targets presented against a sky background was 0.92, while for those presented against a terrain background it was 0.83. However, differences between the conditions in proportion correct ID were not statistically significant when analyzed with Cochran's test for correlated samples ($\underline{Q} = 2.57$, $\underline{df} = 3$, $\underline{p} > .10$; Hays, 1963, p. 628).

Fixed-Wing Sub-Experiment: Engagement, Attrition, and Ordnance Release

In this Experiment, "engaging" the target means firing at it. Both friendlies and hostiles can conceivably be engaged, although engaging friendly aircraft is a serious mistake. The proportion of hostile aircraft engaged is defined as: the number of hostile aircraft fired at, divided by the total number of hostile aircraft presented. "Attrition" means "hitting" or "killing" the target fired at. Attrition also refers only to hostile aircraft. The proportion of attrition is defined as: the number of hostile aircraft killed, divided by the total number of hostile aircraft presented. "Ordnance release" means that the attacking hostile airplane has gotten close enough to the Stinger team to release its payload of bombs, napalm, rockets, cannon fire, etc. "Close enough" is defined as 1.5 kilometers in this Experiment (as per FM 44-23, 1977; Dawdy, 1981). The proportion of ordnance release is defined as: the number of hostile aircraft flying to within 1.5 kilometers of the Stinger team before being killed, divided by the total number of hostile aircraft presented.

The proportions of hostile aircraft engaged, attrited, and releasing ordnance are presented by condition in Table 12. The proportion of hostile aircraft engaged varied between 75 percent and 92 percent. These differences in proportion of engagement are not statistically significant (Cochran's $\underline{Q} = 2.54$, $\underline{df} = 3$, $\underline{p} > .10$). The proportion of aircraft credited as being killed varied from 67 percent to 83 percent. These differences also were not statistically significant ($\underline{Q} = 1.09$, $\underline{df} = 3$, $\underline{p} > .10$). The proportion of hostile aircraft able to approach within ordnance releasing range varied from 75 to 100 percent, depending upon condition. These differences approached statistical significance ($\underline{Q} = 7.20$, $\underline{df} = 3$, $\underline{p} < .10$). The mean proportion of hostile aircraft releasing ordnance for the two conditions of sky background was 0.83, while for terrain background it was 1.00.

Table 12
Proportion Hostile Aircraft Engaged, Attrited, and Releasing Ordnance in Fixed-Wing Sub-Experiment

MiG-27

Event	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Engagement				
Proportion	0.92	0.75	0.83	0.92
N	11/12	9/12	10/12	11/12
Attrition				
Proportion	0.83	0.75	0.67	0.75
N	10/12	9/12	8/12	9/12
Ordnance Release				
Proportion	1.00	1.00	0.75	0.92
N	12/12	12/12	9/12	11/12

Single Rotary-Wing Sub-Experiment: Engagement Event Times

Engagement event times for conditions of the Single RW Sub-Experiment are presented in Tables 13 through 17, by dependent variable type. Times for the detection announcement (Table 13), the IFF-button push (Table 14), and the identification announcement (Table 15) are presented for both hostile and friendly aircraft. Times for IR lock-on (Table 16) and fire-trigger pull (Table 17) are presented only for hostile aircraft.

Detection time is measured from target availability until the detection announcement. For RW aircraft, target availability is defined as that time after the software-generated command to rise when the target has risen far enough to be visible from the weapon position. (This point has also been called "line-of-sight" [CDEC, 1978].) This duration from command to rise to target availability (line-of-sight) was approximately two seconds, varying slightly from helicopter to helicopter, depending primarily upon the relative size and vegetated state of the sand dune behind which each helicopter was hidden. Thus, times in Table 13 represent the time, in seconds, from when the target was available to be seen from the weapon position until the detection announcement was made.

Times from the detection announcement until IFF, ID, lock-on, and fire are presented in Tables 14, 15, 16, and 17, respectively. Thus, the times presented in Tables 14 through 17 record the time in seconds from the

detection event until the later engagement event of interest. This method of calculating the engagement times prevents differences in detection times from biasing the interpretation of all subsequent event times.

Table 13
Detection Time in Seconds for Single Rotary-Wing Sub-Experiment*

Friendly Aircraft: AH-1

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	14.0	9.8	12.2	7.7
SD	6.2	5.0	3.6	1.9
N	8	12	12	12

Hostile Aircraft: Mi-8

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	6.3	4.3	7.6	7.0
SD	3.3	1.9	1.6	3.6
N	10	12	12	12

* Time from target availability (line-of-sight) until detection announcement.

Table 14
IFF Time in Seconds for Single Rotary-Wing Sub-Experiment*

Friendly Aircraft: AH-1

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	1.8	0.3	1.6	0.6
SD	6.1	4.5	2.7	1.2
N	6	7	8	7

Hostile Aircraft: Mi-8

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	0.6	0.7	1.1	0.1
SD	0.9	1.6	1.8	1.7
N	7	10	10	8

* Time from detection announcement until IFF-button push.

Table 15
Identification Time in Seconds for Single Rotary-Wing Sub-Experiment*

Friendly Aircraft: AH-1

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	14.6	6.4	9.2	5.9
SD	10.7	1.9	4.2	1.7
N	7	12	12	12

Hostile Aircraft: Mi-8

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	6.2	6.2	7.7	6.9
SD	2.2	2.0	3.9	4.7
N	10	12	12	12

* Time from detection announcement until ID announcement.

Table 16
Lock-On Time in Seconds for Single Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	8.4	8.1	8.7	8.3
SD	2.6	1.7	3.6	3.4
N	9	9	11	11

* Time from detection announcement until IR lock-on.

Table 17
Fire Time in Seconds for Single Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	10.3	12.2	13.1	11.1
SD	2.2	2.8	2.1	3.2
N	10	10	11	11

* Time from detection announcement until fire-trigger pull.

Table 18 presents the times from ID to fire, for conditions with hostile aircraft. The inclusion of this table allows the reader to compare three critical event times: availability to detect (Table 13), detect to ID (Table 15), and ID to fire (Table 18).

Table 18
ID-to-Fire Time in Seconds for Single Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	4.3	5.9	5.2	5.4
SD	3.0	3.4	3.0	3.1
N	10	10	11	11

* Time from ID announcement until fire-trigger pull.

Ninety-four percent of all single RW aircraft presented were detected (90/96 = 0.94). The six trials on which a target was not detected were all trials in which a helicopter (either friendly or hostile) was presented in frontal aspect against a terrain background. Detection times were analyzed using a three-factor, repeated-measures ANOVA (intent x aspect x background). No main effect of background was found. There was, however, a significant background-by-intent interaction ($F = 22.15$, $df = 1/11$, $p < .001$). Here, the detection time was longer for friendly aircraft with terrain background than for friendly aircraft with sky background, and vice versa for hostile aircraft. There was a significant main effect of aspect ($F = 23.74$, $df = 1/11$, $p < .001$). Aircraft presented in side-view were detected in 7.2 seconds, while those presented in frontal aspect were detected in 10.0

seconds. There was also a significant main effect of intent ($F = 76.44$, $df = 1/11$, $p < .001$). Hostile aircraft were detected in 6.3 seconds, while friendly ones required 10.9 seconds. Finally, the interaction effect of aspect by intent approached statistical significance ($F = 3.56$, $df = 1/11$, $p < .10$). This trend resulted from the fact that the aspect effect (described above) was larger for friendly aircraft than it was for hostiles. None of the remaining interaction effects were significant.

Sixty-six percent of all single RW aircraft presented were interrogated by IFF (63/96 = 0.66). Because so many interrogations were missing, inferential statistical analyses were not carried out. Descriptive analysis of the data presented in Table 14 seems to mirror what was shown for detection times, however. There appears to be no overall influence of background upon IFF time (terrain mean = 0.9 sec., sky mean = 0.9 sec.). Teams seemed to require slightly more time overall to interrogate a target presented in frontal aspect (mean = 1.3 sec.) than one presented in quartering aspect (mean = 0.4 sec.). In addition, friendly targets appeared to be interrogated later (mean = 1.1 sec.) than hostile targets (mean = 0.6 sec.).

Ninety-three percent of all single RW aircraft presented were identified (89/96 = 0.93). The seven trials on which a target was not identified were all trials in which a helicopter (friendly or hostile) was presented in frontal aspect against a terrain background. Identification times were analyzed using a three-factor, repeated-measures ANOVA (intent x aspect x background). Aspect angle was the only statistically significant effect ($F = 10.05$, $df = 1/11$, $p < .05$). Single helicopters when presented in face-view took longer to be identified (9.4 sec.) than when presented in side-view (6.3 sec.). The effect of intent approached significance ($F = 5.70$, $df = 1/11$, $p < .10$), with friendly aircraft requiring more time to be identified (9.0 sec.) than hostiles (6.7 sec.).

Eighty-three percent of all hostile RW aircraft in this Sub-Experiment were locked-onto (40/48 = 0.83). Lock-on times were analyzed using a two-factor, repeated-measures ANOVA (aspect x background). There were no significant differences across conditions for either the main effects or the interaction. Mean overall time from detection to lock-on was 8.4 seconds.

Eighty-seven percent of all hostile RW aircraft in this Sub-Experiment were fired upon (42/48 = 0.87). Fire times were analyzed using a two-factor, repeated-measures ANOVA (aspect x background). There were no significant differences across conditions for either the main effects or the interaction. The mean overall time from detection to fire was 11.7 seconds.

The times from ID announcement to fire were analyzed using a two-factor, repeated-measures ANOVA (aspect x background). There were no significant differences across conditions. However, the time from ID to fire was slightly longer for quartering aspect (mean = 5.6 sec.) than for frontal aspect (mean = 4.8 sec.). This difference approached statistical significance ($F = 6.26$, $df = 1/11$, $p < .10$). The mean overall time from ID to fire was 5.2 seconds.

Single Rotary-Wing Sub-Experiment: Proportion Correct Identifications

Proportion correct (PC) identifications are presented in Table 19 by

conditions of the Sub-Experiment. The mean PC ID rate for friendly aircraft was 0.67, varying between 0.25 for aircraft presented in frontal aspect against a terrain background and 1.00 for those presented in quartering aspect against a sky background. These differences among the conditions for friendly aircraft were statistically significant ($\underline{Q} = 17.25$, $\underline{df} = 3$, $\underline{p} < .001$).

The mean proportion correct ID rate for hostiles was 0.87, varying between 0.83 for aircraft presented against a terrain background and 0.92 for those presented against a sky background. These differences in PC for the hostile targets were not statistically reliable ($\underline{Q} = 0.86$, $\underline{df} = 3$, $\underline{p} > .10$).

Table 19
Proportion Correct Identifications for Single Rotary-Wing Sub-Experiment

Friendly Aircraft: AH-1

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Proportion	0.25	0.58	0.83	1.00
$\underline{N}$	3/12	7/12	10/12	12/12

Hostile Aircraft: Mi-8

Statisic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Proportion	0.83	0.83	0.92	0.92
$\underline{N}$	10/12	10/12	11/12	11/12

Single Rotary-Wing Sub-Experiment: Fratricide

In military parlance fratricide is defined as killing a member of the friendly force (i.e., killing a "brother" combatant). The proportion of fratricide is defined as: the number of friendly aircraft killed, divided by the total number of friendly aircraft presented. Table 20 presents the proportion of friendly aircraft engaged and killed in this Sub-Experiment.

The proportion of friendlies engaged varied from 0.00 to 0.42, depending upon condition. This difference approached statistical significance ($\underline{Q} = 6.50$, $\underline{df} = 3$, $\underline{p} < .10$). Performance was identical for fratricide, in this case, since every fire resulted in a credited "kill". The mean proportion of friendlies engaged and killed when presented against a terrain background was 0.33, while when the same aircraft type was presented against a sky background the mean engagement/fratricide rate was 0.08.

Table 20
Proportion Friendly Aircraft Engaged and Killed in Single Rotary-Wing Sub-Experiment

AH-1

Event	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Engagement				
Proportion	0.25	0.42	0.17	0.00
N	3/12	5/12	2/12	0/12
Fratricide				
Proportion	0.25	0.42	0.17	0.00
N	3/12	5/12	2/12	0/12

Single Rotary-Wing Sub-Experiment: Engagement, Attrition, and Ordnance Release

"Engagement" and "attrition" are defined the same as in the Fixed-Wing Sub-Experiment. In this Sub-Experiment, "ordnance release" means that the attacking hostile helicopter has popped-up from defilade and been allowed to hover long enough to provide effective fire. "Long enough" is arbitrarily defined as 20 seconds in this Experiment. The proportion of ordnance release is defined as: the number of hostile aircraft popping-up and maintaining line-of-sight for at least 20 seconds before being killed, divided by the total number of hostiles presented.

The proportions of hostile aircraft engaged, attrited, and releasing ordnance are presented by condition in Table 21. The proportion of hostile aircraft engaged varied between 83 percent for terrain background and 92 percent for sky background. These differences in proportion engaged were not statistically significant ($Q = 0.86$, $df = 3$, $p > .10$). The mean overall engagement rate was 87 percent.

The rate of attrition of hostile aircraft varied from 75 percent (terrain background, side-view) to 92 percent (sky background, face-view). These differences, however, were not statistically significant ($Q = 1.20$, $df = 3$, $p > .10$). The mean overall attrition rate was 83 percent.

Overall, 75 percent of the hostile aircraft in this Sub-Experiment were able to release ordnance (that is, be visually available for 20 seconds). Ordnance release rate varied from 58 percent (terrain background, side-view) to 100 percent (sky background, face-view). These differences, however, were not statistically reliable ($Q = 6.00$, $df = 3$, $p > .10$).

Table 21
Proportion Hostile Aircraft Engaged, Attrited, and Releasing Ordnance in Single Rotary-Wing Sub-Experiment

Mi-8

Event	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Engagement				
Proportion	0.83	0.83	0.92	0.92
N	10/12	10/12	11/12	11/12
Attrition				
Proportion	0.83	0.75	0.92	0.83
N	10/12	9/12	11/12	10/12
Ordnance Release				
Proportion	0.67	0.58	1.00	0.75
N	8/12	7/12	12/12	9/12

Double Rotary-Wing Sub-Experiment: Engagement Event Times

Engagement event times for conditions of the Double RW Sub-Experiment are presented in Tables 22 through 27, by dependent variable type. All the times presented in these tables were recorded from the Stinger teams' engagements of the first of the two targets detected. That is, two hostile RW aircraft (Mi-8, Mi-24) were presented simultaneously on each trial. The first of these two to be detected and engaged was the one for which the engagement event times were recorded.

Engagement events were defined as in the Single RW Sub-Experiment. Thus, times in Table 22 represent the time in seconds from when the target was available to be seen from the weapon position until the detection announcement was made. Times from the detection announcement until IFF, ID, lock-on, and fire are presented in Tables 23, 24, 25, and 26, respectively. As before, this method of calculating the engagement times prevents differences in detection times from biasing the interpretation of subsequent events.

Table 22
Detection Time in Seconds for Double Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8/Mi-24

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	6.0	5.4	4.4	3.6
SD	2.4	1.8	1.7	1.3
N	12	12	12	12

* Time from target availability (line-of-sight) until detection announcement.

Table 23
IFF Time in Seconds for Double Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8/Mi-24

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	1.1	1.2	2.1	1.1
SD	1.5	2.9	2.6	1.7
N	10	9	9	9

* Time from detection announcement until IFF-button push.

Table 24
Identification Time in Seconds for Double Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8/Mi-24

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	7.6	7.8	7.0	7.8
SD	3.4	5.6	3.7	4.0
N	12	12	12	12

* Time from detection announcement until ID announcement.

Table 25
Lock-On Time in Seconds for Double Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8/Mi-24

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	9.1	7.6	9.9	9.5
SD	2.8	2.0	4.0	3.5
N	12	10	12	10

* Time from detection announcement until IR lock-on.

Table 26
Fire Time in Seconds for Double Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8/Mi-24

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Mean	12.7	10.6	12.8	12.7
SD	2.6	1.6	3.8	4.2
N	12	9	11	10

* Time from detection announcement until fire-trigger pull.

Table 27 presents the times from the identification announcement until the fire-trigger pull. As before, the inclusion of this table allows the reader to compare three critical event times: availability to detect (Table 22), detect to ID (Table 24), and ID to fire (Table 27).

Detection times were analyzed using a two-factor, repeated-measures ANOVA (aspect x background). There was a significant main effect of target background ($F = 12.96$, $df = 1/11$, $p < .01$). Targets presented against a sky background were detected in a mean time of 4.0 seconds, while those presented against terrain required 5.7 seconds. No other main effect or interaction was significant.

The mean detection time over all conditions of the Double RW Sub-Experiment was 4.9 seconds. By comparison, the mean detection time over all conditions of the Single RW Sub-Experiment, for hostile aircraft only, was 6.3 seconds. An analysis of these detection times using a t test for correlated samples showed this difference to be significant ($t = 2.60$, $df = 11$, $p < .05$).

IFF times were analyzed using a two-factor, repeated-measures ANOVA (aspect x background). There were no significant differences found among the conditions. The mean overall time from detect to IFF was 1.4 seconds.

Ninety-seven percent of all presented double RW aircraft were identified (2 aircraft per trial: 93/96 = 0.97). Of the three targets which were not identified, two were presented in frontal aspect against a terrain background and one was presented in side aspect against a terrain background. Identification times were analyzed using a two-factor, repeated-measures ANOVA (aspect x background). None of the differences in identification times were statistically significant. The mean overall time from detect to ID was 7.5 seconds.

Lock-on times also were analyzed using a two-factor, repeated-measures ANOVA (aspect x background). No statistically significant differences were found among the conditions. The mean overall time from detect to lock-on was 9.0 seconds.

Fire times also were analyzed using a two-factor, repeated-measures ANOVA (aspect x background). Again, no statistically reliable differences were found among the conditions. The mean overall time from detect to fire was 12.3 seconds. By comparison, the mean overall time from detect to fire for the hostile aircraft in the Single RW Sub-Experiment was 11.7 seconds. This small difference in overall time was not statistically significant.

The times from identification announcement until fire-trigger pull were also analyzed with a two-factor, repeated-measures ANOVA (aspect x background). No significant differences were found either for main effects or the interaction. The mean overall time from ID to fire was 5.5 seconds.

Table 27
ID-to-Fire Time in Seconds for Double Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8/Mi-24

	Terrain Background		Sky Background	
Statistic	Face-View	Side-View	Face-View	Side-View
Mean	5.1	4.6	6.5	5.8
SD	2.1	2.9	4.3	4.7
N	12	9	11	10

* Time from ID announcement until fire-trigger pull.

Double Rotary-Wing Sub-Experiment: Proportion Correct Identifications

Proportion correct identifications are presented by condition in Table 28. Two hostile targets were presented simultaneously on every trial. Hence, each team had potentially two ID decisions to make on each trial. As

before, the ID decision used throughout this Sub-Experiment was a tactical one. The mean overall PC ID was 0.85. No statistically significant differences were found among conditions (*Q* = 0.39, *df* = 3, *p* > .10).

Table 28
Proportion Correct Identifications for Double Rotary-Wing Sub-Experiment*

Hostile Aircraft: Mi-8/Mi-24

Statistic	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Proportion	0.87	0.83	0.83	0.87
N	21/24	20/24	20/24	21/24

* 2 aircraft per trial x 12 teams = 24 total ID opportunities per condition.

Double Rotary-Wing Sub-Experiment: Engagement, Attrition, and Ordnance Release

The terms "engagement", "attrition", and "ordnance release" are defined in the same fashion as in the Single RW Sub-Experiment. The proportions of aircraft engaged, attrited, and releasing ordnance are presented in Table 29. These data were recorded from the first of the two hostile aircraft to be detected and engaged.

The proportion of aircraft engaged varied between 75 percent (terrain background, side-view) and 100 percent (terrain background, face-view). None of these differences among the conditions were statistically significant (*Q* = 5.00, *df* = 3, *p* > .10). The mean overall percentage of engagement in this Sub-Experiment was 87.

The proportion of aircraft attrited varied between 0.67 and 0.92. Again, these differences were not statistically reliable (*Q* = 4.50, *df* = 3, *p* > .10). The mean overall proportion of aircraft killed was 0.83.

The proportion of hostile aircraft releasing ordnance varied substantially. Ninety-six percent of aircraft (23/24 = 0.96) when presented against a terrain background were able to release ordnance. When these same aircraft were presented against a sky background only half (12/24 = 0.50) were able to release ordnance. These differences in proportion of ordnance release shown in the table were statistically significant (*Q* = 14.76, *df* = 3, *p* < .01).

Table 29

Proportion Hostile Aircraft Engaged, Attrited, and Releasing Ordnance in Double Rotary-Wing Sub-Experiment*

	Mi-8/Mi-24			
	Terrain Background		Sky Background	
Event	Face-View	Side-View	Face-View	Side-View
Engagement				
Proportion	1.00	0.75	0.92	0.83
N	12/12	9/12	11/12	10/12
Attrition				
Proportion	0.92	0.67	0.92	0.83
N	11/12	8/12	11/12	10/12
Ordnance Release				
Proportion	0.92	1.00	0.50	0.50
N	11/12	12/12	6/12	6/12

* Data recorded from engagement of first of the two targets to be detected.

Summary Engagement Times for Hostile Fixed-Wing and Hostile Rotary-Wing Aircraft

RADES recorded the times for each engagement sequence from target availability through fire. This entire engagement sequence can be separated into three critical periods: the time from target availability until detection, the time from detection until identification, and the time from identification until fire. These three periods, plus the total time, are presented by condition for hostile FW and RW aircraft in Tables 30 and 31, respectively.

It can be seen in Table 30 that the mean time for a complete engagement of hostile FW aircraft in this Experiment was less than 45 seconds. In Table 31 it is seen that the mean time for a complete engagement of hostile RW aircraft was less than 20 seconds. This large difference in total engagement time reflected the many differences between FW and RW scenarios in this Experiment. In a FW scenario, the aircraft became available at range and flew toward the team. The engagement sequence was delayed while the aircraft flew to within visual detection range, visual identification range, and weapon engagement range. In a RW scenario, the aircraft popped-up from defilade to become available. Once available, it was within detection, identification, and weapon range. The team's engagement sequence was not delayed while awaiting an ingressing aircraft. This is reflected in the shorter total times presented in Table 31.

Next is presented the relative proportion of the total engagement time which was spent performing each of the three critical tasks for each condition and aircraft type. Table 32 presents these proportions for hostile FW targets, and Table 33 for hostile RW targets. Because of the differences between FW and RW scenarios, proportions will be described separately for each aircraft type.

Table 30
Summary of Critical Engagement Times in Seconds for Hostile Fixed-Wing Aircraft

MiG-27

Engagement Event	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Target Availability to Detection	28.6	29.4	13.1	8.0
Detection to Identification	9.1	9.9	19.7	22.7
Identification to Fire	6.1	5.4	9.1	6.0
Total: Availability to Fire	43.8	44.7	41.9	36.7

Table 31
Summary of Critical Engagement Times in Seconds for Hostile Rotary-Wing Aircraft (Single and Double Combined)

Mi-8/Mi-24

Engagement Event	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Target Availability to Detection	6.1	4.9	6.0	5.3
Detection to Identification	7.0	7.0	7.3	7.3
Identification to Fire	4.8	5.3	5.9	5.6
Total: Availability to Fire	17.9	17.2	19.2	18.2

Table 32
Proportion of Total Engagement Time Spent on Critical Events for Hostile Fixed-Wing Aircraft

MiG-27

Engagement Event	Terrain Background Pop-Up	Terrain Background Lay-Down	Sky Background Pop-Up	Sky Background Lay-Down
Target Availability to Detection	0.65	0.66	0.31	0.22
Detection to Identification	0.21	0.22	0.47	0.62
Identification to Fire	0.14	0.12	0.22	0.16
Total: Availability to Fire	1.00	1.00	1.00	1.00

Table 33
Proportion of Total Engagement Time Spent on Critical Events for Hostile Rotary-Wing Aircraft (Single and Double Combined)

Mi-8/Mi-24

Engagement Event	Terrain Background Face-View	Terrain Background Side-View	Sky Background Face-View	Sky Background Side-View
Target Availability to Detection	0.34	0.28	0.31	0.29
Detection to Identification	0.39	0.41	0.38	0.40
Identification to Fire	0.27	0.31	0.31	0.31
Total: Availability to Fire	1.00	1.00	1.00	1.00

Table 32 shows how great was the impact of target background upon engagement of FW aircraft. When the MiG-27 was flown against a terrain background, two-thirds of the entire engagement period was spent searching for the aircraft. However, when the same aircraft was flown against a sky

background, only one-quarter of the total period was spent searching. This produced an opposite effect upon the proportion of total time spent attempting to identify the aircraft. Aircraft presented against a sky background were detected earlier and then the team spent over half of the total engagement interval attempting to identify the target. Aircraft presented against a terrain background were detected later and, therefore, the team needed to spend only one-fifth of the total interval identifying the (closer) aircraft. Finally, an average of only 16 percent of the total interval was spent finalizing the engagement of the identified, hostile aircraft. Put differently, 84 percent of the total engagement interval was spent with activities up to and including identification.

Table 33 shows that for the hostile RW aircraft approximately 30 percent of the engagement interval was spent searching for the target, 40 percent identifying the target, and a final 30 percent finishing the engagement. Again, the majority of the engagement interval (70%) was spent with activities up to and including identification.

DISCUSSION

Subscale jet and helicopter aircraft were presented to Stinger teams under conditions designed to vary the visual information available. This was done because so many of the current FAAD engagement procedures specifically require visual activities on the part of the air defenders. It was expected that factors which affect visual perception would affect the performance of the FAAD fire unit. As has repeatedly been shown in the Results section, varying the visual information available to air defenders in ways which are likely to occur on the battlefield has a substantial effect upon performance. The relevant variables which influenced performance will be discussed in turn.

Maneuver

There was some evidence to support the hypothesis that air defenders would identify FW aircraft better when the aircraft flew a pop-up maneuver. They were identified earlier during pop-up maneuvers against a sky background. This is probably because aircraft are more exposed during pop-up maneuvers than during lay-down maneuvers. Army doctrine confirms that the pop-up maneuver is more dangerous to the attacking aircraft for this reason (FM 44-3, 1984, p. 2-16).

These results should be viewed with some caution, however, since a similar effect of maneuver was not found by RADES in the range scores. Kirkland (1972), also using range as the measure of performance, found no difference in performance associated with similar maneuvers, when elevation was held approximately constant.

Background

The type of background against which RADES desert-camouflage-colored aircraft were presented had a substantial impact upon performance. Fixed-wing aircraft were detected 4.6 kilometers farther out and over 18 seconds earlier when they were flown against a sky background. These FW aircraft were interrogated 3.6 kilometers farther out and identified 1.1 kilometers farther out when flown against sky. Hostile aircraft when presented against sky were more likely to be locked-onto and fired at while incoming rather than while outgoing.

It is instructive to note that this 4.6-kilometer difference in range at target detection was reduced to 1.1 kilometers at target identification. This is undoubtedly because the teams were in Weapons Control Status Tight and, therefore, had to wait for the aircraft to approach within visual identification range. This mean range for identification was 3.4 km for sky background and 2.3 km for terrain background. ARI representatives at site were made aware of the intense frustration on the part of the teams who detected a target at 8 km and then had to wait with binoculars raised for about 21 seconds while the aircraft approached ever closer, until a visual identification could be made at 3 km. Weapon system or doctrinal requirements that use soldier vision as the final common path to aircraft identification place limitations on the capability of air defenders to engage aircraft at maximum range.

Further evidence of the effect of background upon engagement performance can be seen from an examination of the FW event times. It has already been shown that terrain background lengthened the time from target availability to detect. However, the mean time from detection to fire for hostile FW targets flown against terrain was approximately half as long (14.8 sec.) as that for sky (26.4 sec.). That is, once the terrain-backed targets were detected the engagement sequence proceeded considerably more rapidly. Clearly, this is caused by the reduced time needed to identify the closer aircraft, as shown in Table 30. The time from identification to fire was not affected by background. These effects are summarized in Table 32, which shows that for terrain background the majority of the total engagement interval was spent searching for the target (65%), while for sky background the majority of the engagement interval was spent attempting to identify the target after it had been detected at range (55%).

The performance of Stinger teams engaging RADES RW aircraft was also substantially affected by the presence of a terrain or sky background. In every case where a helicopter was undetected (i.e., completely missed) it had been presented in frontal aspect against a terrain background. Detection times were reliably longer for helicopters presented against a terrain background than for the same helicopters presented against sky. In every case where a target was detected but not identified (i.e., no ID response given) it had been presented against a terrain background. The proportion correct identification rate was higher for single helicopters presented against sky. Finally, the fratricide rate was higher for aircraft presented against terrain than for the same aircraft when presented against sky. Thus, these results using RW aircraft presented well within visual detection range show that air defenders perform more poorly when engaging camouflage-painted aircraft hovering against a terrain background.

Thus it has been amply demonstrated that the performance of Stinger teams will vary widely as a function of the relative perceptual contrast of the target and the background. When contrast is low, as in the case of a desert-camouflage-painted aircraft flying against a desert-terrain background, performance will be poor. When contrast is higher, as in the case of a desert-camouflage-painted aircraft flying against a clear blue sky, performance will be better. The specific visual mechanism necessary to explain these results could be determined with further research. The most likely mechanism is contrast sensitivity (Ginsburg, Easterly, & Evans, 1983).

RADES targets when presented against the sky generally appear as a dark spot against a lighter background. The same targets when presented against the darker terrain background generally appear equal in luminance and "disappear". Currently, RADES does not include a photometer capable of measuring target luminance at range, terrain luminance at range, and luminance of the sky. Independent, photometric verification of the luminance contrast hypothesis must await further research with additional, as yet unpurchased, equipment. Similar contrast effects have been shown previously for FW aircraft models by Baldwin (1973) and for fullscale RW aircraft by CDEC (1978). The Army is aware that conditions of background contrast affect visual detection and identification, and provides this information to Forward Area Air Defenders (e.g., FM 44-30, 1986, pps. 2-2, 2-3, 2-4).

Aspect

Varying the aspect angle of the single RW targets from 0 degrees (frontal) to 90 degrees (quartering) substantially improved engagement performance. This was especially true for the smaller AH-1 helicopter models. On all trials in which a detection was completely missed the helicopter was presented in face-view against a terrain background. Aircraft presented in frontal aspect required more time to be detected than these same aircraft when presented in quartering aspect. This aspect effect upon detection was larger for the AH-1 (4.4 sec.) than for the Mi-8 (1.2 sec.).

Single helicopters in 0-degree aspect were interrogated later than the same helicopters in 90-degree aspect. Identification times also were longer for the aircraft when presented in face-view. Further, identification accuracy was poorer for the AH-1 target when it was presented in frontal aspect (54%) than when it was presented in quartering aspect (79%).

The cause of this effect of aspect upon engagement performance is relative visual magnitude. Any aircraft when presented head-on provides a smaller visual target than when it is presented side-on. Aircraft are designed this way in accordance with obvious aerodynamic principles. Two helicopter types were used in the Single RW Sub-Experiment: AH-1 and Mi-8. A fullscale AH-1 measures approximately 45 feet in length and 11 feet in frontal cross section (FM 44-30, 1986, p. 9-2). The 0-degree, two-dimensional, silhouette of the AH-1 is approximately 27 percent of the visual area of its 90-degree, two-dimensional, silhouette. A fullscale Mi-8 measures approximately 61 feet in length and 18 feet in frontal cross section (FM 44-30, 1986, p. 9-46). Its frontal silhouette is approximately 36 percent of the visual area of its side-view silhouette. Clearly, these two aircraft provide a smaller visual target for engagement when presented in 0-degree

aspect than when presented in 90-degree aspect. Further, this size difference is greater in the case of the AH-1, which is noted to be particularly narrow in frontal cross section. These differences in visual magnitude of the aircraft were mirrored in differences in engagement performance by the air defenders. This effect of presentation aspect has previously been shown for FW models by Baldwin (1973) and by CDEC (1980) for fullscale RW aircraft.

Intent

The intent of the aircraft, whether friendly or hostile, affected performance in the Single RW Sub-Experiment. The hostile Mi-8 was detected 4.6 seconds earlier than the friendly AH-1, with all other experimental conditions held constant. The Mi-8 was also interrogated and identified earlier. In addition, as shown in Table 19, proportion correct identification rate was higher for the hostile helicopter (87%) than for the friendly one (67%).

The reason for these effects is the difference in the visual magnitude between the hostile and the friendly targets. The scale models of the AH-1 presented in this experiment were smaller than the scale models of the Mi-8 because the actual fullscale aircraft are smaller. A fullscale Mi-8 helicopter is larger than a fullscale AH-1 by approximately 36 percent in length, 38 percent in height, and 57 percent in frontal cross section. Thus, the smaller the aircraft, all other things being equal, the more poorly will air defenders perform when attempting to detect and identify it. Baldwin (1973) has reported similar effects of size on the identification of subscale FW models. CDEC (1978) also reported significantly poorer detection performance for the smaller of their two fullscale RW aircraft.

Detection of Single versus Double Rotary-Wing Aircraft

The time taken to detect the first of two hostile RW targets was less than the time taken to detect a single hostile RW target (4.9 sec. versus 6.3 sec.). In the former case there were two engageable targets present within the same 90-degree search sector, separated by approximately 30 degrees. In the latter case only one target was present. Hence, this difference was probably caused by an effectively reduced search sector for the Double RW Sub-Experiment. In one of the earliest reported experiments on the detection and identification of aerial targets by ground observers, Wokoun (1960) found just such an effect of reducing search sector size.

VALIDITY OF THE RADES SIMULATION

A key issue for every simulation is validity. Does the simulation measure what it purports to measure? For RADES this means: Are the engagement event times, ranges, and percentage scores obtained from the engagement of subscale aircraft in RADES comparable to similar indices obtained from similar, but fullscale, field tests and exercises?

This issue was addressed directly in an earlier report entitled "Validation of the Realistic Air Defense Engagement System (RADES)" by Drewfs, Barber, Johnson, and Frederickson (1988). The conclusion of the report was that RADES produced results comparable to those obtained from a wide range of fullscale field tests and that, therefore, RADES is a valid simulation.

However, the issue of the validity of a simulation is a continuing one. Like other simulations, RADES must demonstrate its validity at every opportunity. For this reason we were careful to choose independent variables which had previously been investigated in other tests. It was our intention to investigate some of the critical visual factors which influence the performance of Stinger teams, while simultaneously demonstrating that RADES is a valid FAAD engagement simulation.

We were not frustrated in the attainment of either goal. Previous sections of this report have already described the effects of aircraft maneuver, aircraft background, aircraft aspect, aircraft size, and search sector size on engagement performance. The results found in RADES were consistent with results reported earlier by other investigators. Hence, RADES continues to show itself to be a valid testbed for the investigation of soldier performance issues in FAAD.

CONCLUSIONS

This report describes research performed in the RADES testbed to examine specific doctrinal and tactical conditions which were considered likely to occur on the FAAD battlefield. These conditions--Weapons Control Status Tight, aircraft maneuver, aircraft background, aircraft aspect, and aircraft size--were expected to affect the performance of Stinger teams because these conditions affect the visual characteristics of the presented targets. Target visual characteristics are important because so many of the engagement tasks performed by Stinger teams are visual ones.

There was some evidence that fixed-wing aircraft flying a pop-up attack maneuver were identified earlier than when the same aircraft were flying a lay-down attack maneuver. Such tactics expose more of the airplane to the air defenders for a longer duration.

RADES FW and RW aircraft were detected and identified much more poorly when presented against a low-contrast terrain background than when presented against a higher-contrast sky background.

The combination of background contrast (a threat tactical decision) and Weapons Control Status Tight (an air defense doctrinal decision) produced a serious limitation upon the engagement performance of Stinger teams. Teams in Weapons Tight were able to detect aircraft incoming against a sky background at approximately eight kilometers. Yet because these teams were limited by Weapons Tight Status to making a positive identification based upon visual criteria, they had to wait until the aircraft was much closer (approximately three km) before identifying it visually. Thus, these troops were "waiting" while the aircraft approached to within visual identification range before

determining whether to continue the engagement ("hostile, engage") or cease engagement ("friendly, cease engagement"). If US Army Air Defense intends to engage hostile aircraft at maximum range, doctrine and equipment must be developed which can accurately and reliably replace human eyesight for the tactical identification decision. It is hoped that the currently-being-developed FAAD C2I network will provide this accuracy and reliability.

Varying the aspect angle of the single RW targets from 0 degrees (frontal) to 90 degrees (quartering) substantially improved engagement performance. This was especially true for the smaller AH-1 helicopters. It was argued that this effect was caused by the objective difference in visual magnitude between each helicopter when viewed frontally and when viewed in profile. This difference in magnitude between frontal and quartering views was particularly pronounced for the streamlined AH-1.

Finally, engagement performance was substantially better for hostile compared to friendly single RW targets. It was argued that this effect was caused by the large objective differences in size between the specific hostile and friendly helicopters used. This effect of intent was not, however, merely an artifact of this particular experimental design. Even a casual perusal of the relevant literature will show that Soviet Bloc helicopters are demonstrably larger than US helicopters on the average (cf., Soviet Military Power 1984, p. 60; Soviet Military Power 1987, p. 79; FM 44-30, 1986, pps. 9-2, 9-4, 9-6, 9-8, 9-18, 9-20, 9-22, 9-26, 9-32, 9-38, 9-40, 9-42, 9-44, 9-46, 9-50, 9-54, 9-56, 9-58, 9-62).

Thus, the results show that aircraft which fly pop-up maneuvers, which present a greater target-to-background contrast, which present themselves in quartering aspect, and which are larger are more easily distinguishable targets for Stinger teams. It was precisely to provide objective, data-based answers to these and other important questions of air defense combat developments and training for which the RADES subscale testbed was developed.

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